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Engineering Design Self-Efficacy and Project-Based Learning: How Does Active Learning Influence Student Attitudes and Beliefs?

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Introduction

This work-in-progress research paper seeks to understand how active learning influences student attitudes and beliefs to aid in addressing calls for one-million new STEM graduates in the next decade[1]. With 40% of students currently completing STEM majors, the aim is to increase degree completion to at least 50% by 2022 through improvements in the first two years of undergraduate STEM education. This increase in STEM graduation rates projects to meet at least 75% of the needed one-million graduates. To meet the demands for more high-quality engineers, it is necessary that engineering programs provide an education that graduates more engineers through diverse pathways and provides the engineer of the future[2] skills needed for quick and more innovative solutions to grand challenges[3]. Without doing so successfully, solutions to grand challenges will be slowed or go undeveloped. Thus, for the future of engineering, it is important that instructors embrace new evidence-based means of instruction that ensure our students graduate and with the skills they need to succeed as engineers.

Design, one of these important skills, often portrayed as one of the fundamental roles for engineers, should be an important part of an engineer's education[2]. To promote skill development, research has suggested that instructors work to increase students' self-efficacy[4], or self-belief in the ability to complete a task[5]. Shown to positively correlate with students' grade performance, persistence in college[6,] and increase engineering skill development[7], increasing engineering self-efficacy could be key to creating more engineers[8]. It is important then that we look for and use, evidence-based methods of instruction that increase self-efficacy.

One evidence-based method shown to increase self-efficacy in engineering, that also meets one of PCAST's five recommendations to increase graduation rates[1], is active learning[9]. Besides increasing engineering self-efficacy[8], use of active methods have been shown to be more effective towards improving students' grades when compared to the norm of direct instruction[10] (i.e. lecture). Project-based learning, one active learning method used in engineering, employs the use of cooperative project completion to link learning to real application and increase motivation[7,11]. If project-based learning positively affects students' formation of self-efficacy, including development of engineering self-efficacy, or even design self-efficacy (i.e. students' feelings in their ability to conduct design)[12], project-based learning may prove to be a more effective way to teach engineering skills such as design and help promote increased completion of an engineering degree[2]. To understand how instructors might better develop students' design self-efficacy, we pose the following research question: How does active learning affect students' development of design self-efficacy?

Theoretical Foundations

Self-efficacy examines the belief an individual has in their ability to complete a task[5]. When an individual has high self-efficacy towards a task, they will likely be self-motivated to persist towards completion of that task due to their belief in their ability to succeed[8,13]. In contrast, if an individual has low self-efficacy, they will be less self-motivated to complete tasks[14,15]. Literature has shown active learning significantly increases student performance[10] and project-based learning has been shown to increase engineering self-efficacy[9]. Within this study, we conceptualize self-efficacy specific to students' ability to design in engineering[12]. This conceptualization, called design self-efficacy, looks at student confidence and motivation to complete design tasks, perceptions of their ability to succeed in design tasks, and their anxiety in doing such tasks. Students who feel confident, feel motivated, feel able to succeed, and feel a low level of anxiety are perceived as having high design self-efficacy. [12].

Course Structure

The Class and Instructional Methods

The study was done within a large Engineering Statics course (n=333) that made use of active learning methods. The course consisted of two 75-minute lectures per week. The lecture hall consisted of multiple rows of tables stretching to the back of the room with a large amount of walking room between rows. Three separate classrooms observations were conducted to determine classroom setup; one observation at the beginning and two closer to the end of the course. Field notes were taken, looking at what instructional methods were used in the course. Results identified the use of project-based learning and problem-based learning. This study focuses on the project-based component of the course.

Bridge Project and Experimentation Labs

The last three weeks of the course, students were assigned a group project related to bridge-building. Students had two weeks to complete the project. Course specifications included: use of Balsa wood only, length, width, and height restrictions, specified loading plate at the top of the bridge, the bridge had to be determinate (able to be statically solved using normal means of statics), and all math and simulations had to prove what load the bridge could hold as a comparison for testing. At the end of the two weeks, students had three days to break their bridges in a campus laboratory while determining the highest efficiency of load held to bridge weight.

Quantitative Data Collection and Analysis

Survey Administration

A modified version of Carberry's Design Self-Efficacy Instrument[12] was first administered at the end of the second day of the course. The instrument was answered on paper by 74 students (22.1% response rate). Questions asked within the protocol, included students' perceptions of their: confidence, motivation, ability to succeed, and anxiety to conduct engineering design as well as sub-categories for each design self-efficacy construct. These sub-categories included identifying a design need, researching a design need, developing design solutions, selecting the best possible design, constructing a prototype, evaluating and testing a design, communicating a design, and redesigning. The questions could be responded to on a 10 point scale anchored from 0 and 100. Two additional questions asked students to rank four items they believe would motivate them to complete a design task, and to rank four items they believed would be reasons they would not succeed in completing a design task. Students' demographics relating to their year in engineering, gender identity, sexual orientation, race, major, and minor were also collected. There were 56 items in the final instrument. For all surveys, students were given the opportunity to earn a $10 electronic gift card.

A similar survey, shown in Appendix A, was given at the end of the semester that also included short answer questions about what aspects of the class were most beneficial to students' ability to learn classroom material, conduct engineering design, and develop as an engineering student. The questions were designed to understand the role active learning may serve as a tool for teaching engineering design. 256 students completed the survey (76.9% response rate). For all surveys, students were again given the opportunity to earn a $10 electronic gift card.

Analysis of Survey Data

After each survey administration, paper responses were hand-entered and imported into R Statistical Software[16]. An exploratory factor analysis (EFA), with a Promax rotation[17], was conducted on each of the four sets of nine subcategories. Students who did not complete the entirety of the survey were removed from the individual data sets prior to each EFA. To see how subsequent factors were correlated with each other following the EFA, a correlation matrix was done. Tests were run to understand students' design self-efficacy changes over time. Prior to testing for significant changes, a Shapiro-Wilk Normality Test[18] was run to determine normality of the data. Results of this comparison test were considered significant at the 0.05 level. These pre- and post- results were plotted within a box plot to provide visual representation of each test.

Qualitative Data Collection and Analysis

At the conclusion of the course, students were offered five points of extra credit in the class, on a 1000-point scale, to complete a 15 to 30-minute short-answer journal entry. Students completed the entry outside of class via Learning Management Software. The journal protocol, shown in Appendix B, consisted of 12 short answer questions requiring students to answer each with a minimum of two sentences to receive extra credit. Students were provided the list of design subcategories, identical to those within the survey shown in Appendix A, to help them answer questions such as the ones below related to confidence.

Journal entry responses (n=165) were collected. For use of this work-in-progress, and to better explain the fullness of their experiences, only (n=8) participants who completed both surveys, as well as a journal entry, were used to allow for mixing of the data during analysis. Demographics of the eight participants within this work-in-progress can be found in Table 1:

Pseudonym	Major	Year	Gender
Barney	Civil Engineering	2	Male
Billy	Mechanical Engineering	3	Male
Carl	Unknown	2	Male
Lily	Civil Engineering	2	Female
Nick	Mechanical Engineering	2	Male
Stella	Civil Engineering	3	Female
Stuart	Mechanical Engineering	2	Male
Tracy	Chemical Engineering	2	Female

Table 1: Participant list. Students are listed with gender, year, and major.

To explore in detail how students' active participation in the bridge project affected their development of design self-efficacy, an interpretative phenomenological analytical (IPA) method, used prior in engineering, was used[19,20]. An IPA looks at a persons' personal perceptions of a specific experience while also letting the researcher interpret it for the use of data collection[21,22]. For each individual, written entries, individual survey factor averages, and short answer portions of the second survey administration were read and listened to using a text-to-speech function of Adobe Reader. Comments were then generated by the lead author on printed copies of the journal entries.

All methodologies used for data collection in this study were approved by the institutional IRB board. Students' received extra credit for completion of the journal assignment regardless of the choice to participate in the research study. All students were provided information letters prior to each round of data collection and were given the option to opt out of the study at any time. Opt procedures went through the study PI rather than the instructor so as to reduce potential coercion.

Results

Pre-Survey Results

After data cleaning, responses of (n=60) participants from the pre survey were used for an initial EFA. A scree plot of the pre survey data indicated that there were three latent factors within the data. The results of the EFA, shown in Figure 1, indicated student perceptions of confidence and success loaded together while motivation and anxiety loaded separately.

Pre Survey EFA

	Factor1	Factor2	Factor3
Q1a	0.864		
Q1b	0.766		
Q1c	0.802		
Q1d	0.935		
Q1e	0.840		
Q1f	0.711		
Q1g	0.777		
Q1h	0.720		
Q1i	0.780		
Q3a	0.887		
Q3b	0.921		
Q3c	0.760		
Q3d	0.891		
Q3e	0.854		
Q3f	0.763		
Q3g	0.865		
Q3h	0.783		
Q3i	0.859		
Q2a		0.869	
Q2b		0.919	
Q2c		0.728	
Q2d		0.910	
Q2e		0.802	
Q2f		0.853	
Q2g		0.831	
Q2h		0.809	
Q2i		0.922	
Q6a			0.900
Q6b			0.964
Q6c			0.846
Q6d			0.876
Q6e			0.848
Q6f			0.730
Q6g			0.784
Q6h			0.719
Q6i			0.906

Question Labels
Categories
Q1: Confidence
Q2: Motivation
Q3: Success
Q6: Anxiety
Subcategories
a: Conduct engineering design
b: Identify a design need
c: Research a design need
d: Develop design solutions
e: Select the best possible design
f: Construct a prototype
g: Evaluate and test a design
h: Communicate a design
i: Redesign

Figure 1: Pre survey exploratory factor analysis shown with a cutoff of 0.4. All variables loaded within the three factors categorizing questions related to confidence and success in factor 1, motivation into factor 2, and anxiety into factor 3.

Each set of nine sub-categories was averaged into individual scores for confidence-success, motivation, and anxiety. These three categories were then tested for correlation, shown in Table 2:

Pre Survey Correlation Matrix

	avgCS	avgmotivation	avganxiety
avgCS		0.5143559	-0.2944401
avgmotivation			-0.3033196
avganxiety			

Table 2: Correlation matrices of the three EFA factors from pre survey administration. Pre-survey results show a high correlation between motivation and the combined confidence-success factor. All factors showed a low, and negative, correlation to anxiety.

Pre-survey results showed a high correlation between motivation and the combined confidence-success factor (0.51). The combined confidence-success factor and motivation did not correlate highly or positively with anxiety (-0.29, and -0.30, respectively). These results help explain the three-factor grouping results of the EFA.

Post-Survey Results

After data cleaning, responses of (n=215) were used in a post EFA. A scree plot, of the post-survey data showed the use of three factors was again sufficient to proceed with the EFA. The results of the EFA, below in Figure 2 with a cutoff of 0.4, showed again that perceptions of confidence and success were able to be grouped while motivation and anxiety could still be considered their own factors.

Post Survey EFA

	Factor1	Factor2	Factor3
Q1a	0.733		
Q1b	0.649		
Q1c	0.753		
Q1d	0.836		
Q1e	0.758		
Q1f	0.804		
Q1g	0.918		
Q1h	0.702		
Q1i	0.800		
Q3a	0.917		
Q3b	0.717		
Q3c	0.765		
Q3d	0.890		
Q3e	0.901		
Q3f	0.805		
Q3g	0.948		
Q3h	0.728		
Q3i	0.885		
Q2a		0.869	
Q2b		0.856	
Q2c		0.835	
Q2d		0.909	
Q2e		0.751	
Q2f		0.787	
Q2g		0.781	
Q2h		0.797	
Q2i		0.814	
Q6a			0.896
Q6b			0.918
Q6c			0.845
Q6d			0.939
Q6e			0.931
Q6f			0.889
Q6g			0.930
Q6h			0.815
Q6i			0.884

Question Labels
Categories
Q1: Confidence
Q2: Motivation
Q3: Success
Q6: Anxiety
Subcategories
a: Conduct engineering design
b: Identify a design need
c: Research a design need
d: Develop design solutions
e: Select the best possible design
f: Construct a prototype
g: Evaluate and test a design
h: Communicate a design
i: Redesign

Figure 2: Post survey exploratory factor analysis shown with a cutoff of 0.4. All variables again loaded within the three factors categorizing questions related to confidence and success in factor 1, motivation into factor 2, and anxiety into factor 3.

Post survey correlation matrix results (Table 3) again indicate a higher correlation than the pre between motivation and the combined confidence-success factor (0.66). Anxiety once again did not correlate positively or highly with the confidence-success factor, or motivation (-0.32, and -0.14, respectively).

Post Survey Correlation Matrix			
	avgCS	avgmotivation	avganxiety
avgCS		0.6645886	-0.3181206
avgmotivation			-0.1482526
avganxiety			

Table 3: Correlation matrices of the three EFA factors from post survey administration. Results show a high correlation between motivation and the combined confidence-success factor. All factors showed a low, and negative, correlation to anxiety.

Seeing similar results to those of the pre survey, these results again help demonstrate consistent emergence of the three-factor grouping results of the EFA.

Longitudinal Changes over the Course of the Semester

Results of a Shapiro-Wilks Normality Test (shown in Table 4) suggests that data for all three factors for both pre- and post- data can be considered a normal distribution. Thus, a pairwise t-test was used.

Pre Survey Normality		
Factor	**W-Statistic**	**P-Value**
Confidence - Success	0.9713	0.1665
Motivation	0.9776	0.8694
Anxiety	0.9841	0.6889

Post Survey Normality		
Factor	**W-Statistic**	**P-value**
Confidence - Success	0.9762	0.9953
Motivation	0.9530	0.1729
Anxiety	0.9808	0.4645

Table 4: Results of Pre and Post Shapiro-Wilks Normality Tests. P-values less than 0.05 suggest that data is not normally distributed.

Results of the pairwise t-tests, shown visually in Figures 3-5, showed a significant increase between the pre- and post- results of confidence-success ($p = 0.002$), and no significance between the pre- and post- results of motivation and anxiety ($p = 0.200$ and $p = 0.479$, respectively). Of the tested population, the average combined confidence-success factor had an increase from 6.8 (pre) to 8.1 (post). Motivation had very little increase from 8.0 (pre) to 8.4 (post). Anxiety, unlike the others, had a decrease from 4.9 (pre) to 4.4 (post).

To better describe the trends of the quantitative results, we examined changes in design self-efficacy of select participants individually and further explored their responses with their qualitative journal entries. With some close or slight deviation, Barney, Billy, Carl, Nick, and Tracy showed general increases in design self-efficacy over the semester while Lily, Stella, and Stuart showed a general decrease (Table 5).

Pseudonym	Confidence	Motivation	Success	Anxiety
Barney	Increase	Decrease	Increase	Decrease
Billy	Increase	Increase	Increase	Increase
Carl	Increase	Decrease	Increase	Increase
Lily	Decrease	Decrease	Decrease	Increase
Nick	Increase	Increase	Increase	Decrease
Stella	Decrease	Increase	Increase	Increase
Stuart	Decrease	Increase	Decrease	Decrease
Tracy	Increase	Increase	Increase	Decrease

Table 5: Participant list with pre and post survey results. Barney, Billy, Carl, Nick, and Tracy showed general increases in design self-efficacy over the semester while Lily, Stella, and Stuart showed a general decrease.

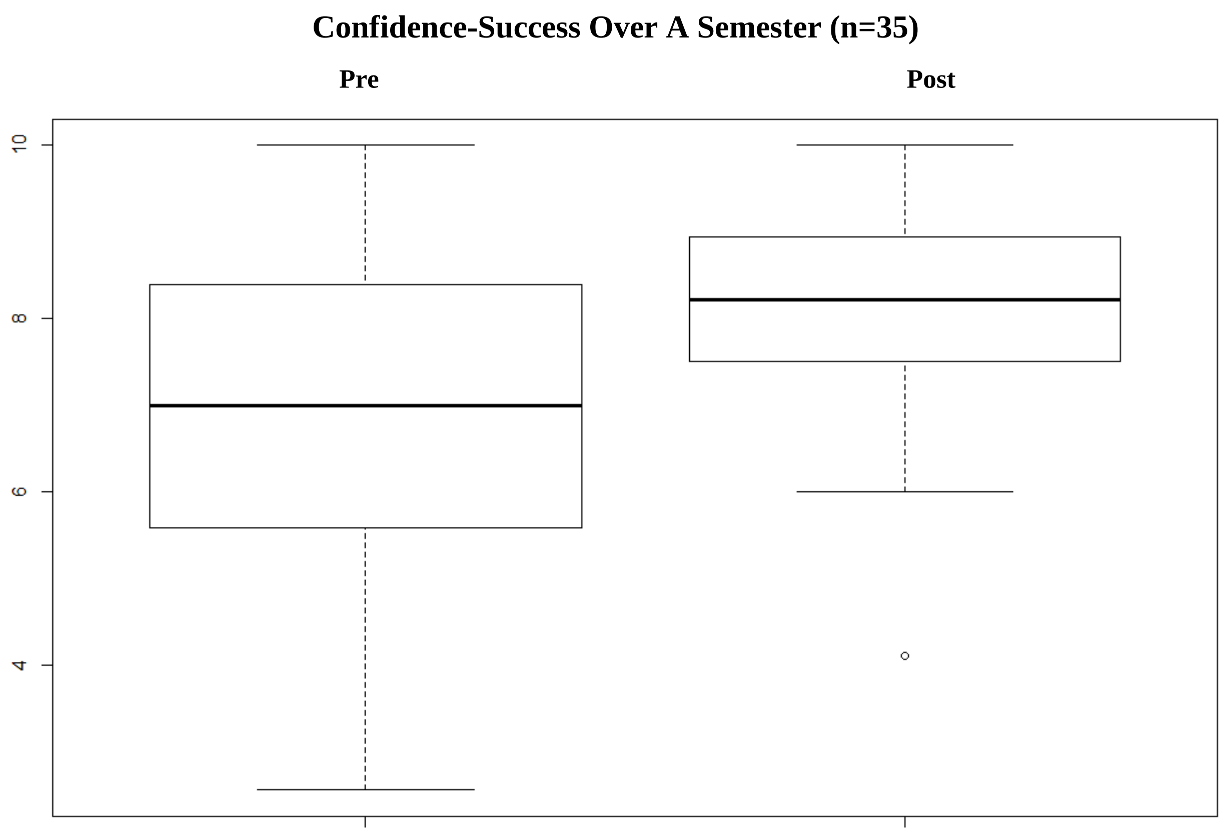

Figure 3: Students had a significant increase (p-value = 0.002) of confidence-success over the semester from a mean of 6.8 (pre) to 8.1 (post).

Motivation Over A Semester
(n=35)

Pre **Post**

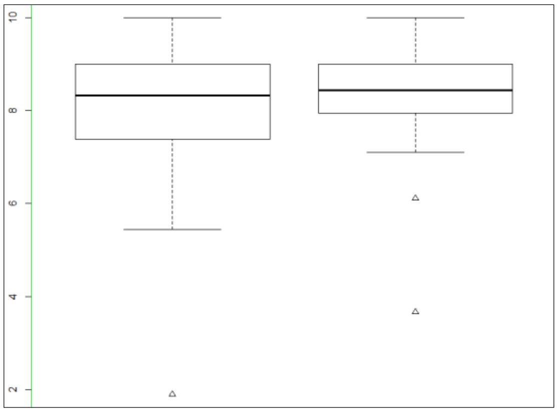

Figure 4: Students had very little increase of motivation over the semester. The mean increased from 8.0 (pre) to 8.4 (post).

Anxiety Over A Semester
(n=35)

Pre **Post**

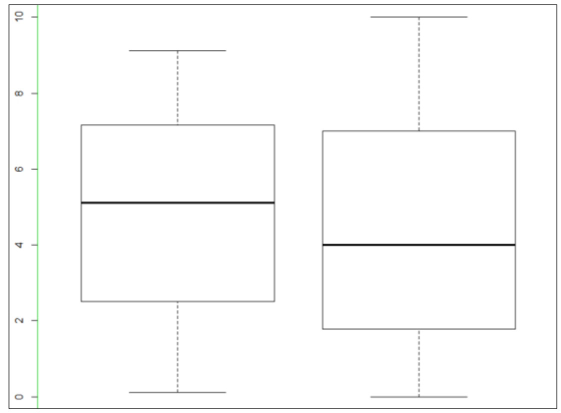

Figure 5: Students had a decrease in anxiety from 4.9 (pre) to 4.4 (post). As students highly spread from the mean, the changes cannot be considered significant.

Journal Results

Through a review of an initial set of written journals of the bridge project, themes emerged. These initial themes are as follows:

1. Students determined what parts of design they were competent in, and were not competent in, which motivated and/or demotivated them towards or away from different aspects of design, respectively.
2. Students linked in-class content to real design opportunities.
3. Students felt they could link the successes and failures of the experience to different aspects of their future goals.
4. Students felt they could have succeeded more given the opportunity to complete the design process and redesign.
5. All throughout, students mention the use of team members as resources for content and skill competence.

In designing, we see what parts of designs students feel competent and not competent doing. Tracy was one of these individuals:

> I felt fine about everything except constructing a prototype. I am very confident in calculations and coming up with ideas, but I was worried that the way we put the bridge together could have a huge effect on the result of our experiment. [Now,] I feel much more confident in selecting the best possible design. [Doing calculations and coming up with ideas] were my favorite part of this and I look forward to doing them in the future. – Tracy

Tracy learned what parts of design she was not good at in regards to the project. She shows anxiety, but it does not seem to deviate her from design. She discusses that as a result of what the project had to offer, as well as her personal enjoyment, she now feels more confident and motivated to do certain parts of design in the future. Not every participant ignored their perceived weaknesses; some avoided it all together. In Stuart's case, it was due to fear:

> I don't feel confident in the calculations of the bridge. Trusses are not my strong suit so I decided not to do the calculations and risk errors. Trusses are confusing to me and I get lost in all the members. I seem to do the equations wrong which messes up my calculations. After the bridge project, I feel I can succeed in designing a bridge and building and also testing it. I [still] don't feel like I can do the calculations until I get a better understanding of trusses. – Stuart

We can see Stuart has anxiety with doing design-related calculations and unlike others, reacts accordingly by not doing them at all, and indirectly stating his teammates did them instead. Like others, Stuart has figured out what he is competent at. Even though calculations are not a strength, use of the project seems to have helped him increase perceptions of competence in other design skills.

While experimenting with skill use, students discussed how they could apply course content to what they had in mind for their bridge designs.

> Coming up with design solutions, our team spent a few hours brainstorming up ideas for the bridge. We identified that an arch span would force all the weight applied to it into the sides of the fixture. It would then be easier on the materials by forcing all members into compression. The arch became the best possible design because it met the criteria of being both lightweight and able to carry an immense load. – Nick

Without a project to complement course work, Nick might not have had to ability to link concepts to practical use. Using content not only helps with the creation of his project, but also lets the project reinforce content for him. Not only did students feel that the project could help them now, but they could also link it to their future goals:

> I realized I have a lot to learn and I can't wait to see how I would turn out when I go into the real world with actual knowledge of how to design a bridge. I feel like statics is the foundation and the basic steps I need. – Stella

Stella saw where the project was relevant to her future. Because of the experience, she's motivated to get to her future in engineering as well.

Many students discussed wishes for more time on the project from the professor. This was not only because they felt shortened for time, but because some students felt they could have redesigned a better bridge that would have had even better success. Testing of the bridge allowed them to see how their bridge reacted to forces discussed in the class and choose a path to redesign.

> We [the team] were very successful in coming up with a design and implementing the construction of said design. If I was to redesign the bridge knowing what I know today, I would have done a double arch design with one of the arches going to the top of the fixture and the other compressing into the sidewall of the fixture, making the bridge even stronger than its predecessor. I felt comfortable with all the [design] aspects except the time limit which did not allow for any real redesign time. – Nick

The ability to redesign would have made Nick feel much more successful about the design process. When his team tested their bridge, they saw how it physically responded and thus created conclusions on how to more confidently redesign in the future.

Discussion

Participants in this study completed both pre- and post-surveys related to engineering design self-efficacy, and qualitative journal entries relating to their perceptions of engineering design self-efficacy due to participation in a single project-based learning experience.

Quantitative results showed very little change in students' overall motivation and anxiety to do engineering design but did show significant increases in students' perceptions of confidence and success. The results of this study show a strong correlation between students' confidence and motivation as well as motivation and success, which might support prior research regarding the positive effects self-efficacy has on students' development of self-motivation[14] and the effects motivation has on students' perceptions of their ability to succeed in a task[13]. Additionally, EFA results showed a strong correlation between perceptions of confidence and ability to succeed; similar to that of engineering studies relating to performance-competence based identity constructs[23,24].

Qualitative results show us that students connect with different parts of design. Students find parts of design they are good at, and not good at. Pairing those with results of confidence-success correlations related to performance-competence in the engineering role identity literature[23,24]., it might be said that project-based learning allows students to better explore and find their identity as an engineer, which is important to developing motivation for a future career[25]. This identity might also be backed up through by constructs of recognition by self or other group members at times of success or failure. Also shown by qualitative results are students' wants to take explored results from their project tasks, whether success or failure, and take the project to the full and successful completion students believe they can achieve, while also finding task relevance. Literature explores this same context, called task-identity, in industry[26]. Within, employees often have wants to take a physical task to full completion when assigned it because of a personally created identity to that task. If this applies to engineering students' wants to complete the design cycle in full, it might be said that use of project-based learning allows engineering students create a design task-identity that develops design self-efficacy now and for the future. If task-identity proves positive to developing design self-efficacy now, it might allow students to find increased task relevance (perceived instrumentality), important to development of a future time perspective and future possible self (FTP and FPS, respectively)[19,20].

The usefulness of project-based learning may also support aspects of the MUSIC model (eMpowerment, Usefulness, Success, Interest, and Caring)[27]. The model says that to achieve motivation, instructors should ensure students can: feel empowered to make decisions about their learning, find relevance for their future, believe they can succeed, are interested in the content, and that they are cared for as a learner and person. Within the project-based learning environment, students may feel empowered in their learning by being active and decisive within it and towards something of interest. When paired with task-identity, they may be finding relevance to their futures. Lastly, if students are engaged, students might feel recognized by the instructor. In the case of project-based learning, enjoyment, and empowerment, students might additionally feel the instructor cares about their learning, personal self, and achievement of future goals; additionally motivating them towards learning skills for the future. Further work and additional journal analysis from our study is needed to support these conclusions and connections and to determine how trends found in this work transfer to a wider segment of the engineering population.

Conclusions, Future Work, and Implications for Practice

Students have shown significant wants to not only be engaged and learn in the design process but also to take the project to a level of success they believed necessary. Use of task-identity models[26] may help to shed light on these needs for completion and their relationship to creating an engineering identity and developing design self-efficacy. If task-identity work can be applied to project-based learning and development of skills, it may point to instructors needs to not only use project-based learning in the classroom but also to create projects for students that allow them to go through the entire design process.

Students also discuss important personal gains in skill development as a result of projects. If the use of projects increases student's feelings of design self-efficacy, it may point to the need to use multiple various projects that allow students to attempt and learn different skills. As students who do not have self-efficacy towards a task may instead have increased anxiety towards it, it may be important for instructors to look for related issues through project assessment earlier and scaffold later projects towards individual gains in those areas. By working to increase student design self-efficacy through ways such as project-based learning, we may be able to further develop student engineering skills necessary for the engineer of 2020 to complete future engineering grand challenges.

Future work will look to see whether other methods of active learning, such as problem-based learning[7], show similar increases of student design self-efficacy and will seek to understand further how active learning environments increase student development of design self-efficacy and task-identity. Work will also look to see whether students studied cross-semester within this study show further increases in design self-efficacy and task-identity as they continue through additional active-learning taught courses. Additional plans for related creative work will also seek to understand how participation in active learning environments affects students changing definitions of design.

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Appendix A

Engineering Identification & Design Self-Efficacy Survey

We are interested in knowing what Major(s), Minor(s), and/or Emphasis' you are currently pursuing or have interest in pursuing in the future as well as what you believe about your current abilities. Your participation now and/or in the future cannot affect your grade.

You must be 18 years of age or older to participate in this study.

Self-efficacy Questions – Please answer all of the following questions fully by selecting the answer that best represents your beliefs and judgment of your current abilities. Answer each question in terms of who you are and what you know today about the given tasks. There are no right or wrong answers.

1. Rate your degree of confidence (i.e. belief in your current ability) to perform the following tasks by recording a number from 0 to 100. (0 = cannot do at all; 50 = moderately can do; 100 = highly certain can do)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	O	O	O	O	O	O	O	O	O	O	O
Identify a design need	O	O	O	O	O	O	O	O	O	O	O
Research a design need	O	O	O	O	O	O	O	O	O	O	O
Develop design solutions	O	O	O	O	O	O	O	O	O	O	O
Select the best possible design	O	O	O	O	O	O	O	O	O	O	O
Construct a prototype	O	O	O	O	O	O	O	O	O	O	O
Evaluate and test a design	O	O	O	O	O	O	O	O	O	O	O
Communicate a design	O	O	O	O	O	O	O	O	O	O	O
Redesign	O	O	O	O	O	O	O	O	O	O	O

2. Rate how motivated you would be to perform the following tasks by recording a number from 0 to100. (0 = not motivated; 50 = moderately motivated; 100 = highly motivated)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	O	O	O	O	O	O	O	O	O	O	O
Identify a design need	O	O	O	O	O	O	O	O	O	O	O
Research a design need	O	O	O	O	O	O	O	O	O	O	O
Develop design solutions	O	O	O	O	O	O	O	O	O	O	O
Select the best possible design	O	O	O	O	O	O	O	O	O	O	O
Construct a prototype	O	O	O	O	O	O	O	O	O	O	O
Evaluate and test a design	O	O	O	O	O	O	O	O	O	O	O
Communicate a design	O	O	O	O	O	O	O	O	O	O	O
Redesign	O	O	O	O	O	O	O	O	O	O	O

3. Rate how successful you would be in performing the following tasks by recording a number from 0 to 100. (0 = cannot expect success at all; 50 = moderately expect success; 100 = highly certain of success)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	O	O	O	O	O	O	O	O	O	O	O
Identify a design need	O	O	O	O	O	O	O	O	O	O	O
Research a design need	O	O	O	O	O	O	O	O	O	O	O
Develop design solutions	O	O	O	O	O	O	O	O	O	O	O
Select the best possible design	O	O	O	O	O	O	O	O	O	O	O
Construct a prototype	O	O	O	O	O	O	O	O	O	O	O
Evaluate and test a design	O	O	O	O	O	O	O	O	O	O	O
Communicate a design	O	O	O	O	O	O	O	O	O	O	O
Redesign	O	O	O	O	O	O	O	O	O	O	O

4. Rank the following choices form 1-4 in order of what would be your incentive to participate and complete an engineering design task (4 = highest incentive to do the task; 1 = the least incentive).

	1 = lowest	2	3	4
You find it interesting and/or fun	O	O	O	O
To learn something (acquire a skill)	O	O	O	O
Compensation (money or a class grade)	O	O	O	O
Just to get it done if required	O	O	O	O

5. Rank the following possible reasons from 1-4 for why you might be unsuccessful in solving an engineering design problem (4 = the most likely reason for failure; 1 = the least likely reason).

	1 = least likely	2	3	4
Insufficient effort	O	O	O	O
Lack of experience	O	O	O	O
Lack of knowledge	O	O	O	O
Low ability	O	O	O	O

6. Rate your degree of anxiety (how apprehensive you would be) in performing the following tasks by recording a number from 0 to 100.
(0 = not anxious at all; 50 = moderately anxious; 100 = highly anxious)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	O	O	O	O	O	O	O	O	O	O	O
Identify a design need	O	O	O	O	O	O	O	O	O	O	O
Research a design need	O	O	O	O	O	O	O	O	O	O	O
Develop design solutions	O	O	O	O	O	O	O	O	O	O	O
Select the best possible design	O	O	O	O	O	O	O	O	O	O	O
Construct a prototype	O	O	O	O	O	O	O	O	O	O	O
Evaluate and test a design	O	O	O	O	O	O	O	O	O	O	O
Communicate a design	O	O	O	O	O	O	O	O	O	O	O
Redesign	O	O	O	O	O	O	O	O	O	O	O

<u>Demographic Information</u> – Please fill out the following background information as it best applies to you.

7. First and Last Name: (Print Neatly)

____

8. Email you use for coursework: (Print Neatly). All communications will be confidential and your email will NOT be disclosed to any third party.

____

9. What year are you currently completing in engineering? (Choose one)

O 1st Year   O 2nd Year   O 3rd Year   O 4th Year or more

10. How do you describe your gender identity? (Mark all that apply)

O Female

O Transgender

O Male

O Cisgender

O Genderqueer

O Agender

O A gender not listed:

____

11. How do you describe your sexual identity? (Mark all that apply)

O Heterosexual/Straight

O Homosexual / Gay / Lesbian

O Bisexual

O Asexual

O A sexuality not listed:

____

12. With which racial and ethnic group(s) do you identify? (Mark all that apply)

O American Indian or Alaska Native

O Hispanic, Latino, or Spanish origin

O White/Caucasian

O Asian

O Middle Eastern or North African

O Black or African American

O Native Hawaiian or Other Pacific Islander

O Another race or ethnicity:

____

13. Which of the following majors are you currently pursuing? (Choose all that apply)

O Chemical Engineering

O Civil Engineering

O Computer Science & Engineering

O Electrical Engineering

O Environmental Engineering

O Engineering Physics

O Material Science & Engineering

O Mechanical Engineering

O Mining Engineering

O Other/Non-Engineering (Please describe):

____

14. Which of the following minors/emphasis', if any, are you currently pursuing with your degree? (Choose all that apply)

O Civil Engineering

O Cyber Security

O Computer Science & Engineering

O Digital Interactive Games

O Electrical Engineering

O Environmental Engineering

O Engineering Physics

O Extractive Metallurgy

O Material Science & Engineering

O Mechanical Engineering

O Mining Engineering

O Nanotechnology

O Renewable Energy

O Unmanned Autonomous Systems

O Other/Non-Engineering
(Please describe):

____

15. Are there any other majors, minors, emphasis, or interests (not necessarily listed previously) that you are interested in pursuing in the future? (Please describe)

____

____

16. What methods of instruction used in this class were the most beneficial to your ability to <u>learn material</u>? Why?

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17. In thinking about those methods of instruction, which have been most beneficial in your <u>ability to conduct engineering design</u>? Why?

18. Which methods of instruction have been most beneficial to you in your <u>development as an engineering student</u>? Why?

Appendix B

Authors' Note: Below is a compressed version of the journal instrument. Actual use of the instrument consists of online text boxes where students may paragraph-response answers to each question.

Design Self-Efficacy Journal Instrument

By submitting this journal entry, you agree that you have read the information letter for participating in a Research Study contained in the same folder as this [redacted] and you consent to participate in a research study. You also agree that you are 18 years of age or older.

Thinking about the experiment you completed for [redacted], please answer the following questions about your abilities in engineering design to the best of your ability. To receive extra credit, all questions, including smaller sub-questions, <u>must</u> be answered and answers should be at least two sentences each. There are no right or wrong answers.

<u>Question 1:</u> Please briefly describe the experiment you did for [redacted]. What was the goal of the experiment? What steps did you take to design a solution?

<u>Question 2:</u> Engineering design may include but is not limited to:

- Identifying a design need
- Developing design solutions
- Selecting the best possible design
- Constructing a prototype
- Evaluating and testing a design
- Communicating a design
- Redesigning

What parts of the experiment did you feel confident about designing? What parts of the experiment did you not feel confident about designing? What about the experiment made you feel this way?

<u>Question 3:</u> After doing this experiment, what parts of engineering design do you feel more or less confident to be able to design in the future? Why? You may want to refer to design components mentioned in question 2.

<u>Question 4:</u> What parts of the experiment did you feel you were motivated to design? What parts of the experiment did you not feel motivated to design? What about the experiment made you feel this way? You may want to refer to design components mentioned in question 2.

<u>Question 5:</u> After doing this experiment, what parts of engineering design do you feel more motivated to do in the future? What parts of engineering design do you not feel more motivated to do in the future? Why? You may want to refer to design components mentioned in question 2.

Question 6: What parts of the experiment did you feel you were successful in design? What parts of the experiment did you feel you were not successful in designing? What about the experiment made you feel this way? You may want to refer to design components mentioned in question 2.

Question 7: After doing this experiment, what parts of engineering design do you feel more or less able to succeed in doing in the future? Why? You may want to refer to design components mentioned in question 2.

Question 8: What, if any, do you think would be reasons why you would not succeed in designing an engineering design task in the future?

Question 9: What parts of the experiment did you feel comfortable designing? What parts of the experiment did you not feel comfortable designing? Why? You may want to refer to design components mentioned in question 2.

Question 10: After doing this experiment, what parts of engineering design do you feel or not feel comfortable about doing in the future? Why? You may want to refer to design components mentioned in question 2.

Question 11: Why do you solve engineering design problems?

Question 12: Do you have any more you'd like to say about the project, your ability to complete it, or your ability to design a solution in the future? If yes, please describe.